



TTF III Coupler test & operating results

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1. TESLA Power Couplers

Coupler type		FNAL	TTF I	TTF II	TTF III	TTF IV	Saclay/Orsay
cold part	window	conical	cyl.	cyl.	cyl.	cyl.	disk
	coax diameter, mm	40	40	40	40	80	80
	Impedance, Ohm	50	50	70	70	70	50
warm part	window	planar, WG	cyl.	planar, WG	cyl.	cyl.	planar, WG
	coax diameter, mm	60	40	60	60	80	80
	Impedance, Ohm	50	50	50	50	50	50
coupling		adjustable	adjustable	adjustable	adjustable	fix	fix
bias		no	no	yes	yes	yes	
TiN coating		F	F	F	D	D	
test stand	2Hz / 500µs	1MW	1MW	2MW	1MW		
	2Hz / 1.3ms	1MW	1MW	1.8MW (1)	1MW		
TW	cold test done	yes	yes	no	no		
horiz. test	2Hz / 500µs	1MW	1MW	1MW	1MW		
	10Hz / 1.3ms	33MV/m	25MV/m	35MV/m	35MV/m		
SW	cold test done	yes	yes	yes	yes		
fabricated total		13	4	20	22 (40)	2	
assembled to		Mod.1*, 2*	Mod.1	Mod.1*, 3, 4	Mod.5, 2* (6)		

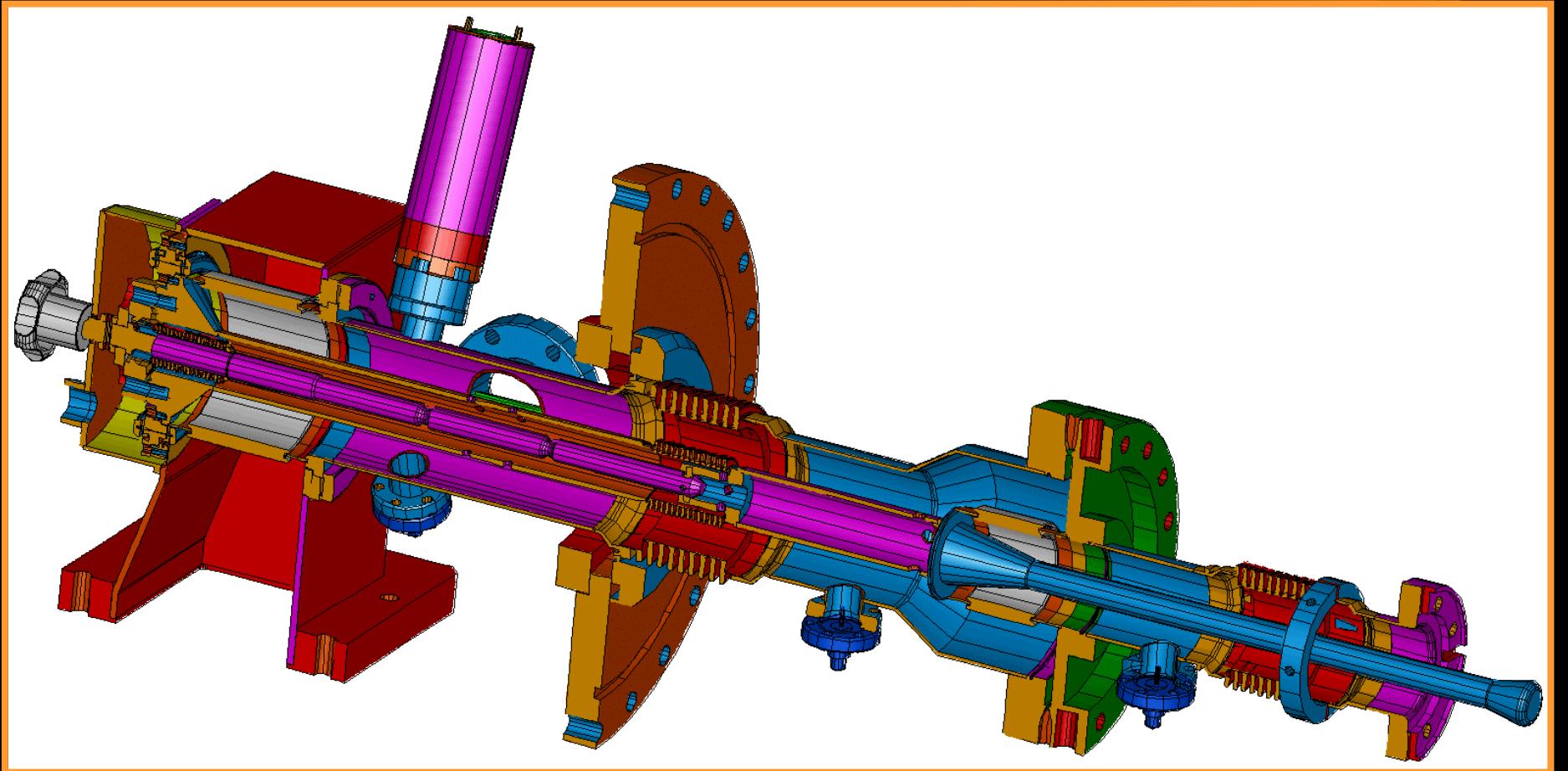
Coupler Specifications (1)

frequency	1.3 GHz
operation	pulsed: 500 μ sec risetime, 800 μ sec flat top with beam
two windows (TiN coated)	<ul style="list-style-type: none">• safe operation• clean cavity assembly for high gradients
2 K heat load	0.06 W
4 K heat load	0.5 W
70 K heat load	6 W
isolated inner conductor	bias voltage, suppressing multipacting
diagnostic	sufficient for safe operation and monitoring

Coupler Specifications (2)

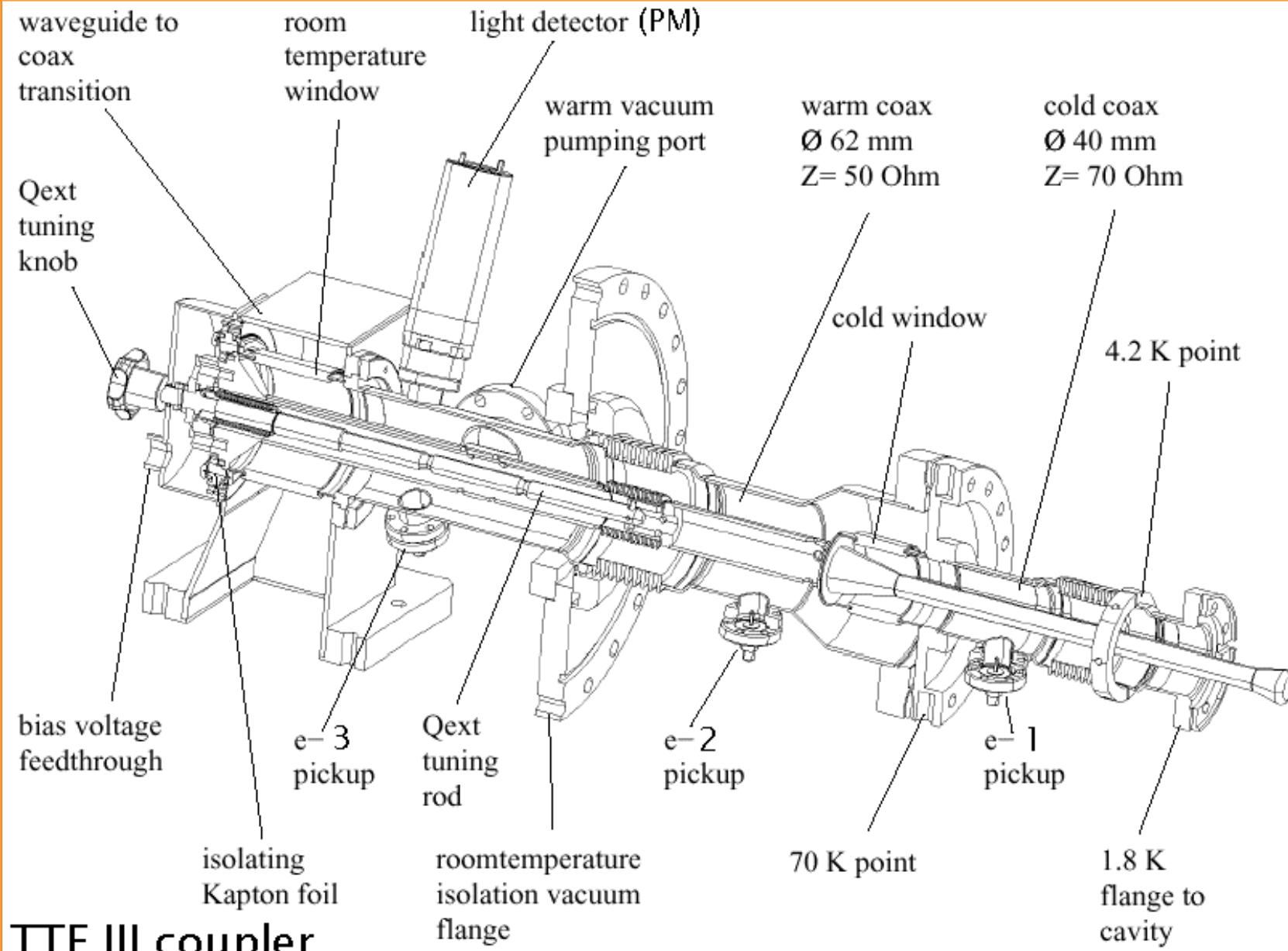
	TTF	TESLA 9cell / upgrade	XFEL
Peak power + 27% control margin	250 kW	250 kW / 500 kW	150 kW
Repetition rate	10 Hz	5 Hz	10 Hz
Average power	3.2 kW	3.2 kW / 6.4 kW	1.9 kW
Coupling (Q_{ext})	adjustable $(10^6 - 10^7)$	fixed $(3 \cdot 10^6)$	not decided $(4.6 \cdot 10^6)$

2. TTF III Coupler design



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Sensors layout

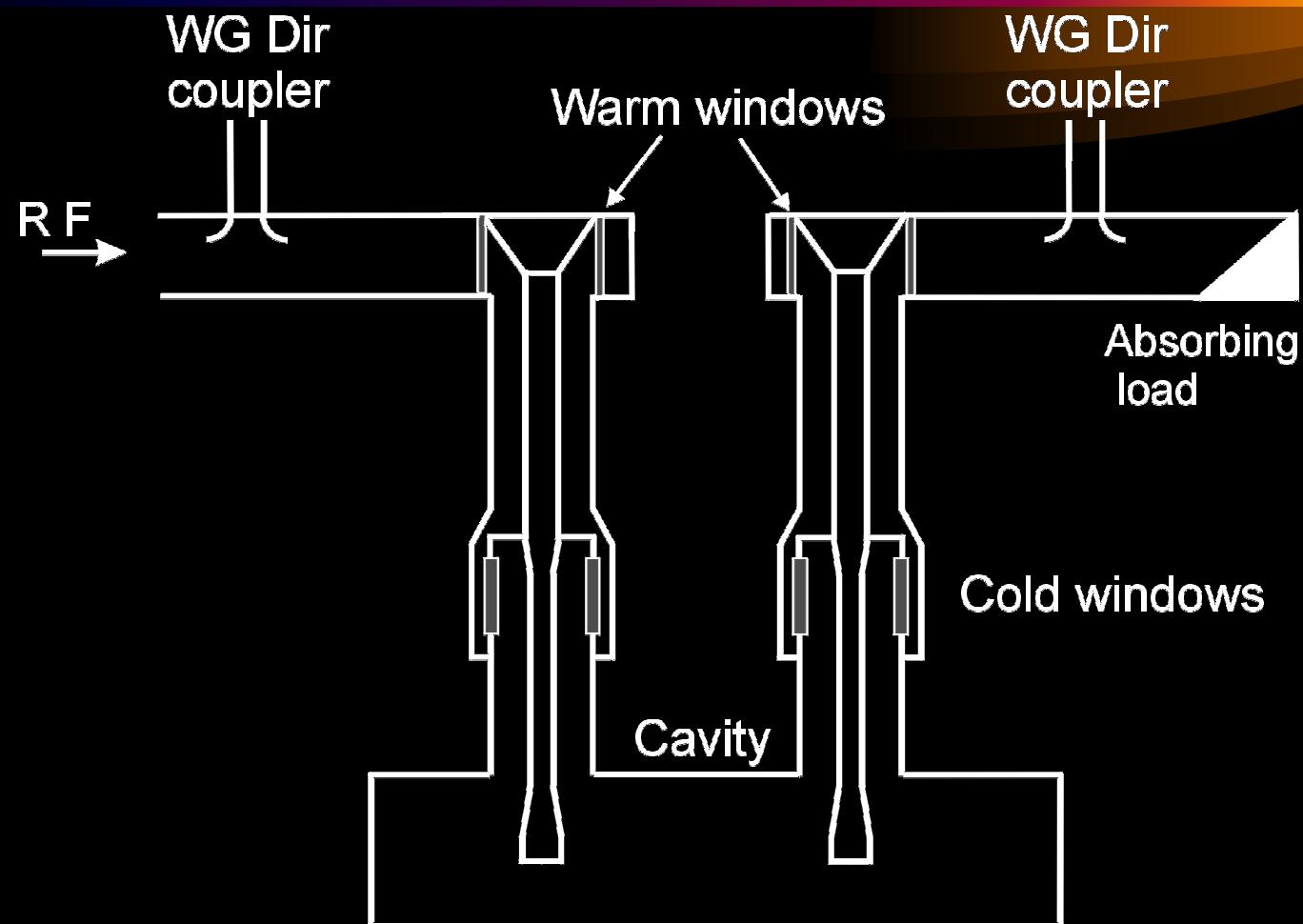


Design improvements

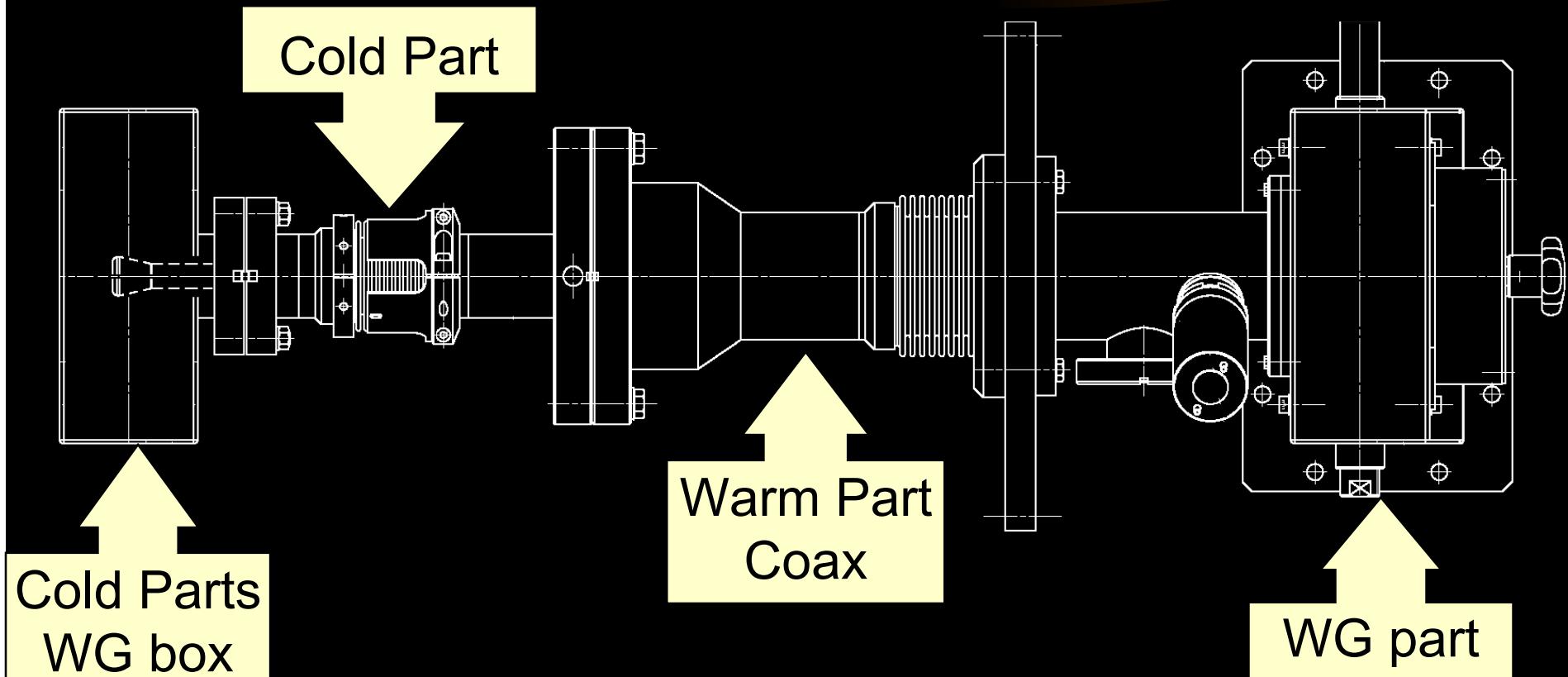


1. WG part: new parts made of copper
2. WG part: coaxial to WG connection improved strength plus RF seal
3. WG part: PT100 temperature sensor instead of IR
4. WG part: HV connection filter coil made bigger

3. Coupler Test stand



Coupler layout

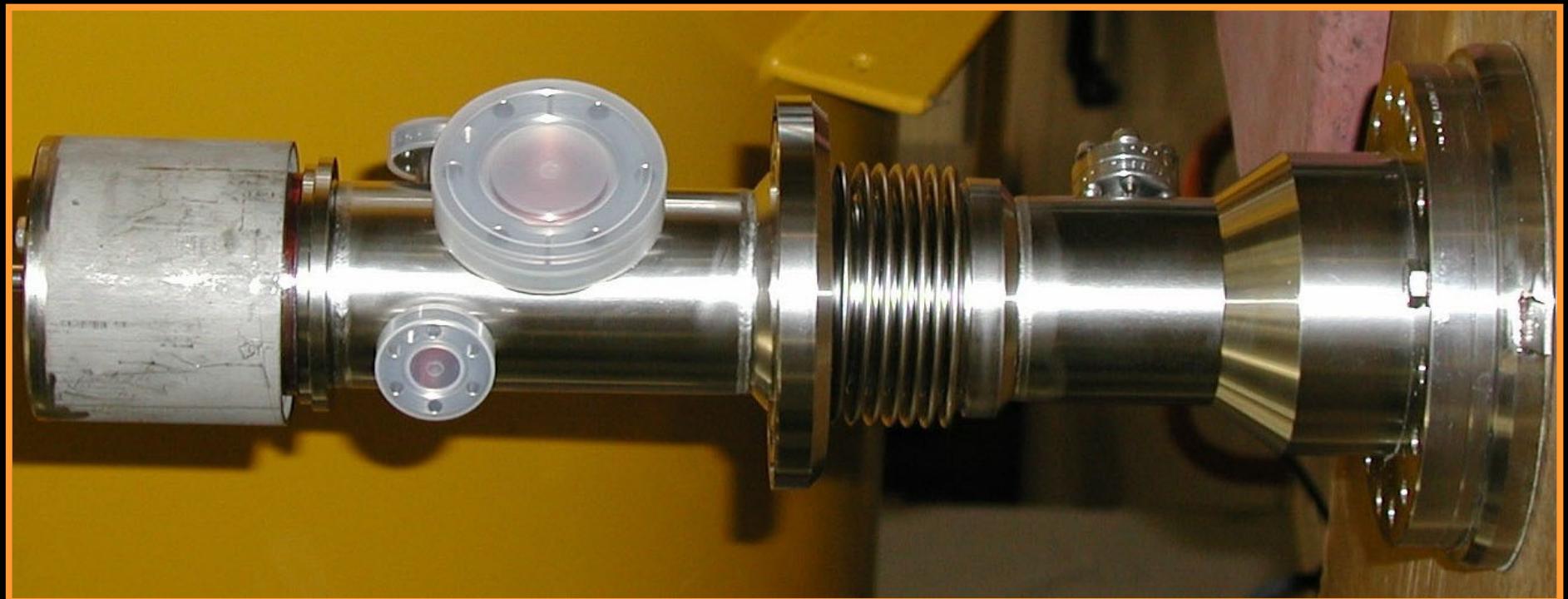


Cold part

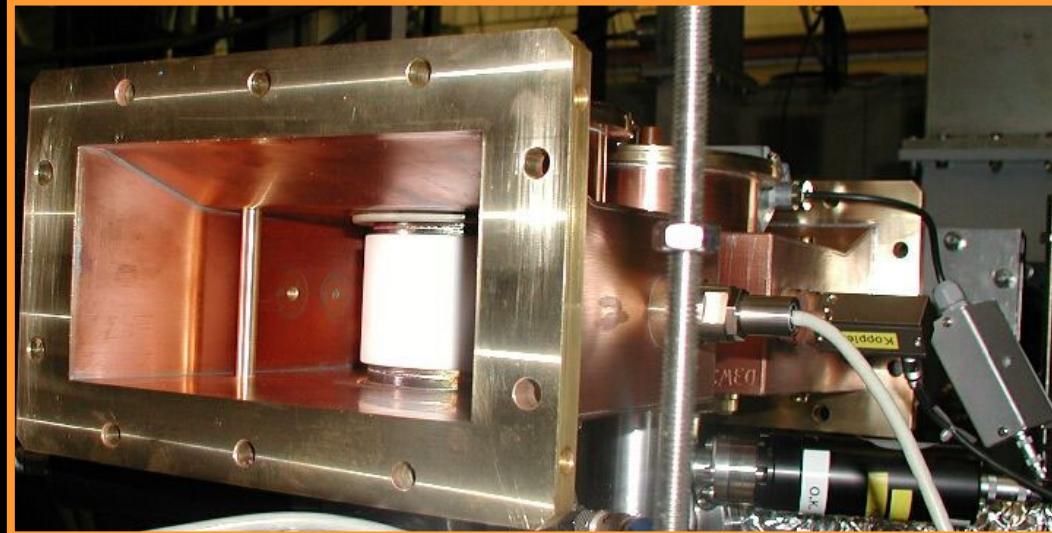


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Warm part

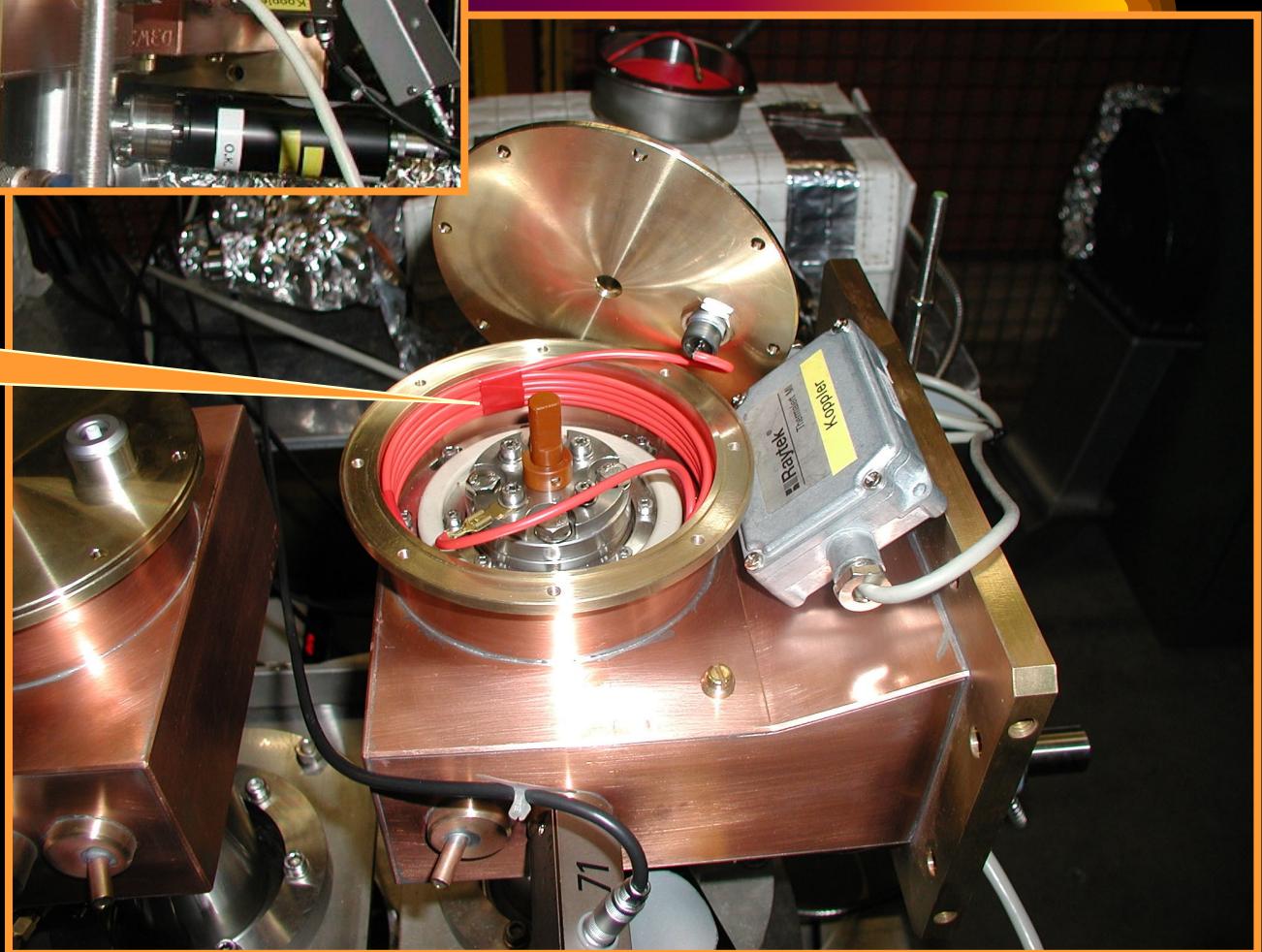


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WG part

HV input
coil

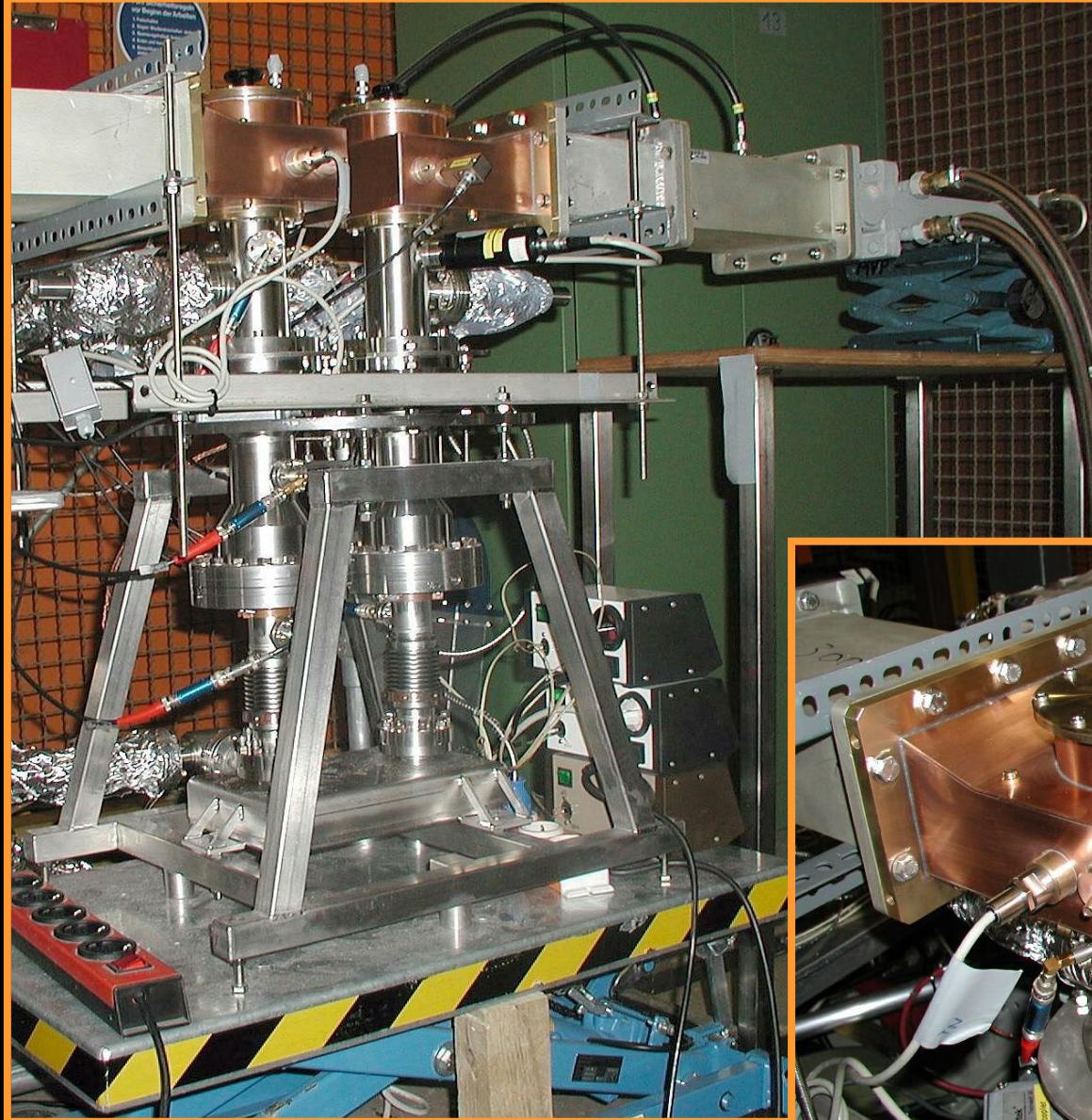


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Test Stand

TTF III couplers
assembled on
the test stand,
without
WG parts



Test Stand



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Assembly and treatment



- Coupler cold parts are assembled in the class 10 clean room, then couplers are assembled in a mobile clean room class 100.
- All coupler parts later being part of a coupler vacuum system must be stored in a dry nitrogen gas.
- Time when coupler vacuum system parts being exposed to the air must be minimized.
- Warm and cold ceramic windows must be protected during the assembly and transport (protecting caps are used).
- Before RF test couplers are baked for about 3 days at the temperature of 150°C.

Test procedure

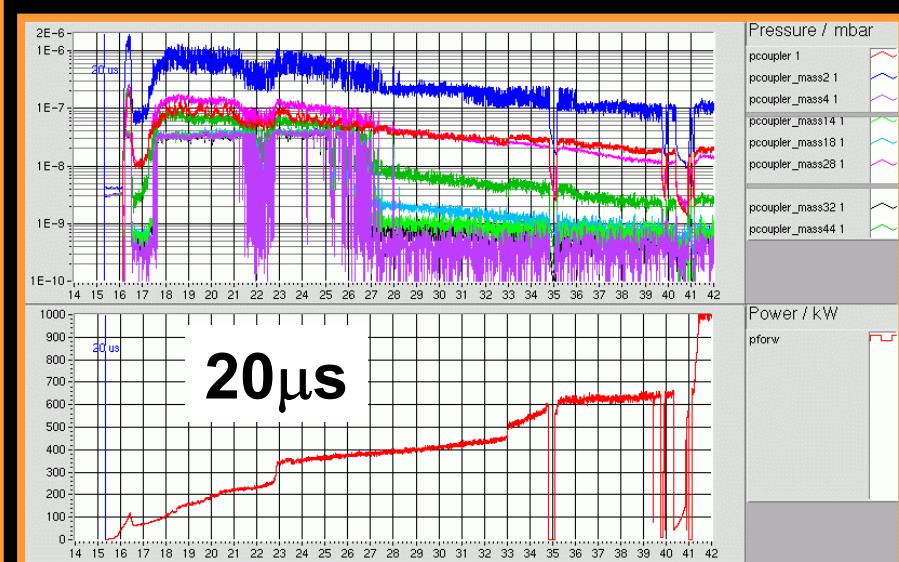
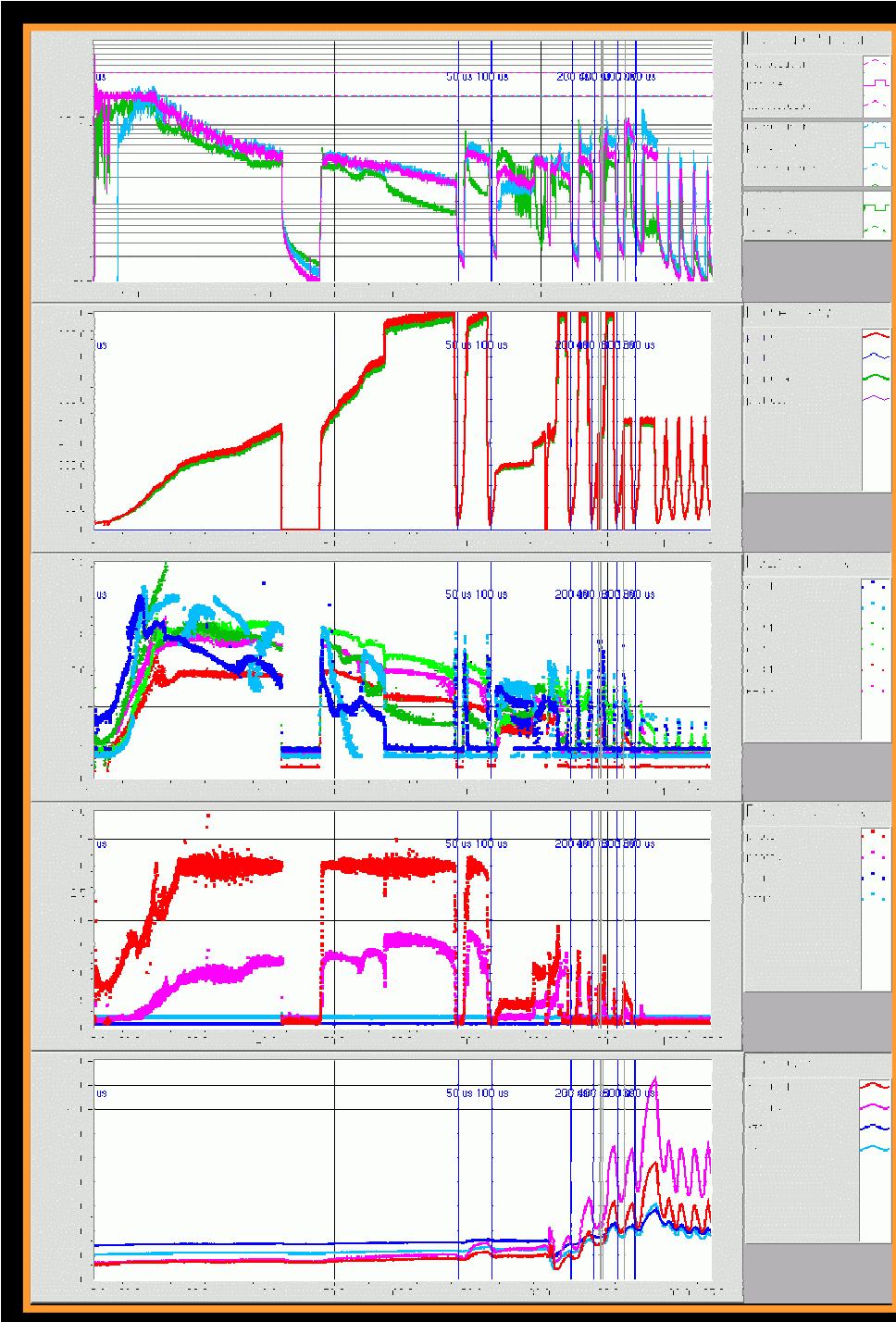
1. Coupler processing sequence (travelling wave) 2 Hz rep.rate

- pulse length 20 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 50 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 100 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 200 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 400 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 800 µs, max. power 0.5 MW, power inc. 0.2 dB/min
- pulse length 1300 µs, max. power 0.5 MW, power inc. 0.2 dB/min
- power sweep @ 1.3 ms pulse, 50..500 kW of power

2. Coupler processing limits

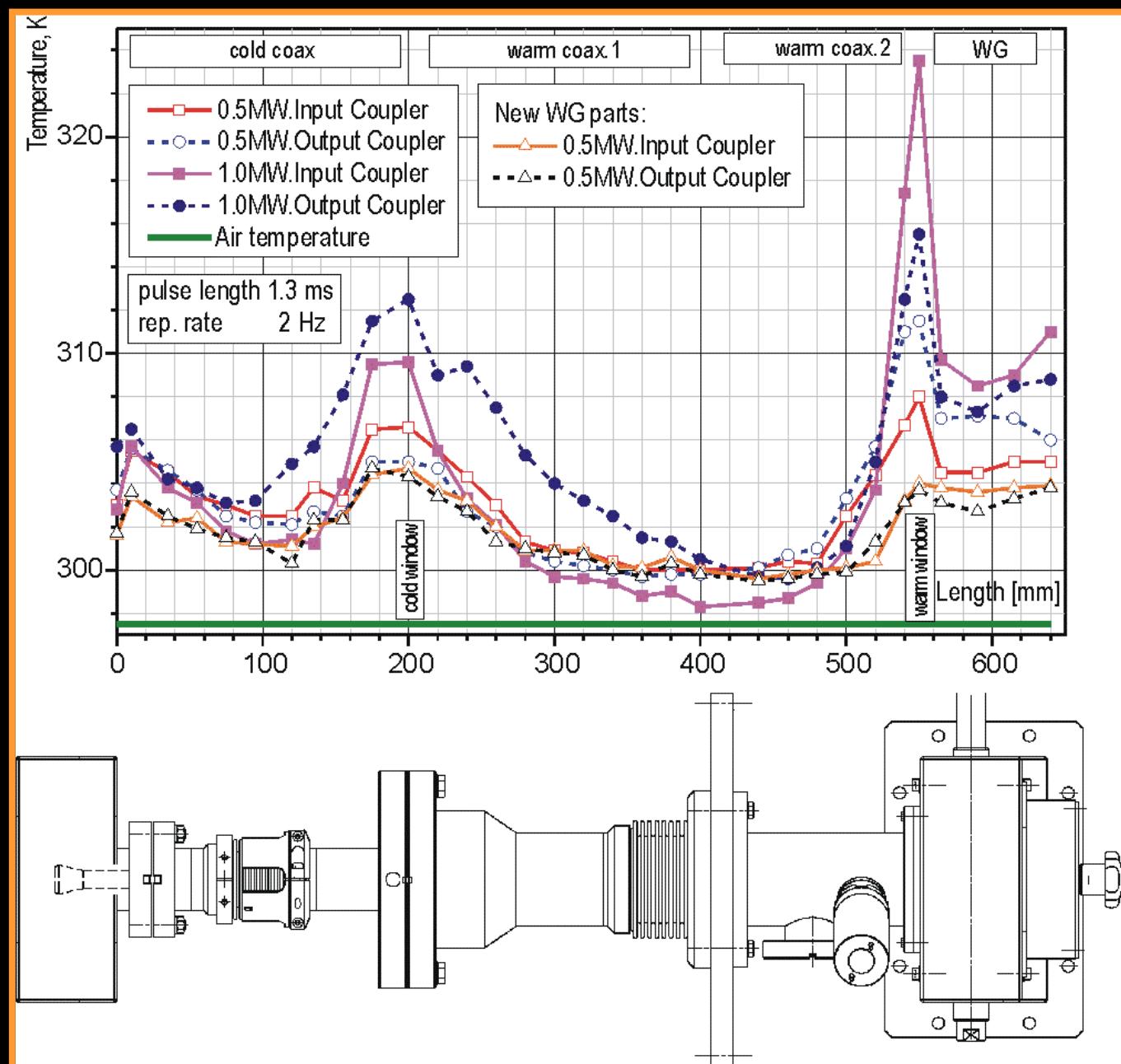
- e- pick-up IL signal: 5 mA (1.2 V on the IL card)
- Light (PM) IL signal: 1 Lux (10 V on the IL card)
- Vacuum pressure: 10^{-6} mbar
- Ceramics temperature: 85°C
- WG sparks: stop if any

Test run

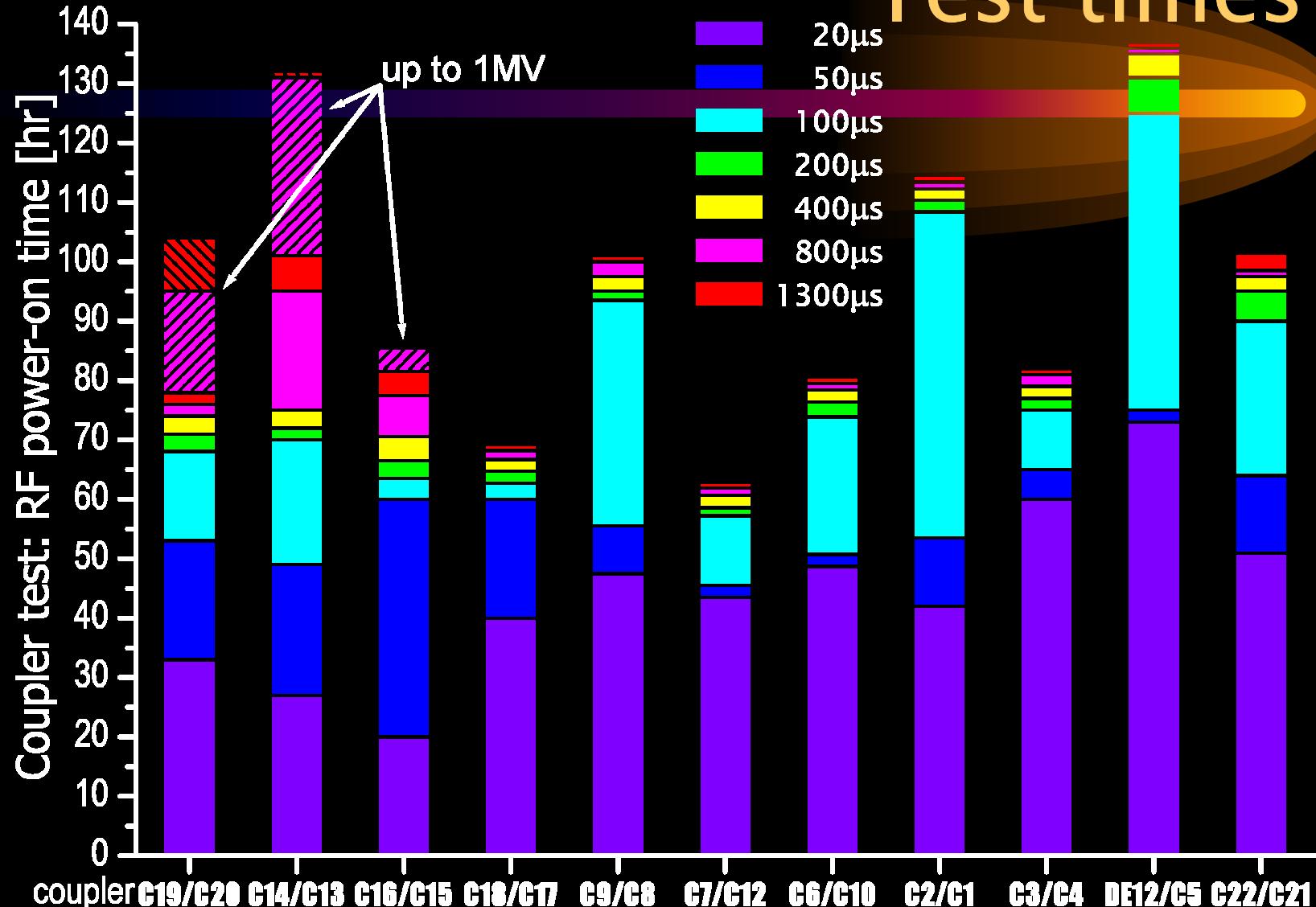


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Coupler temperature

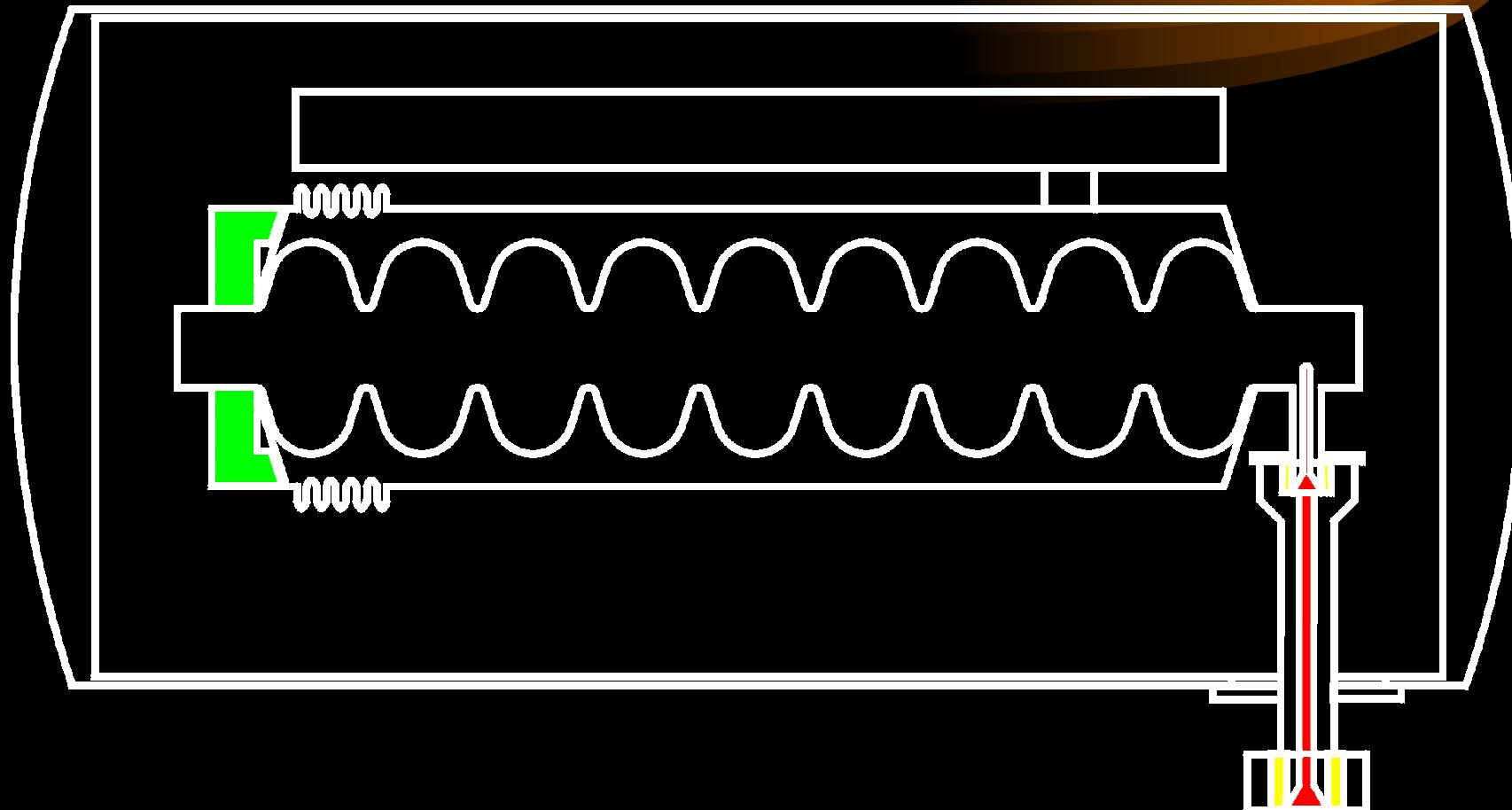


Test times



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4. Horizontal Test Stand



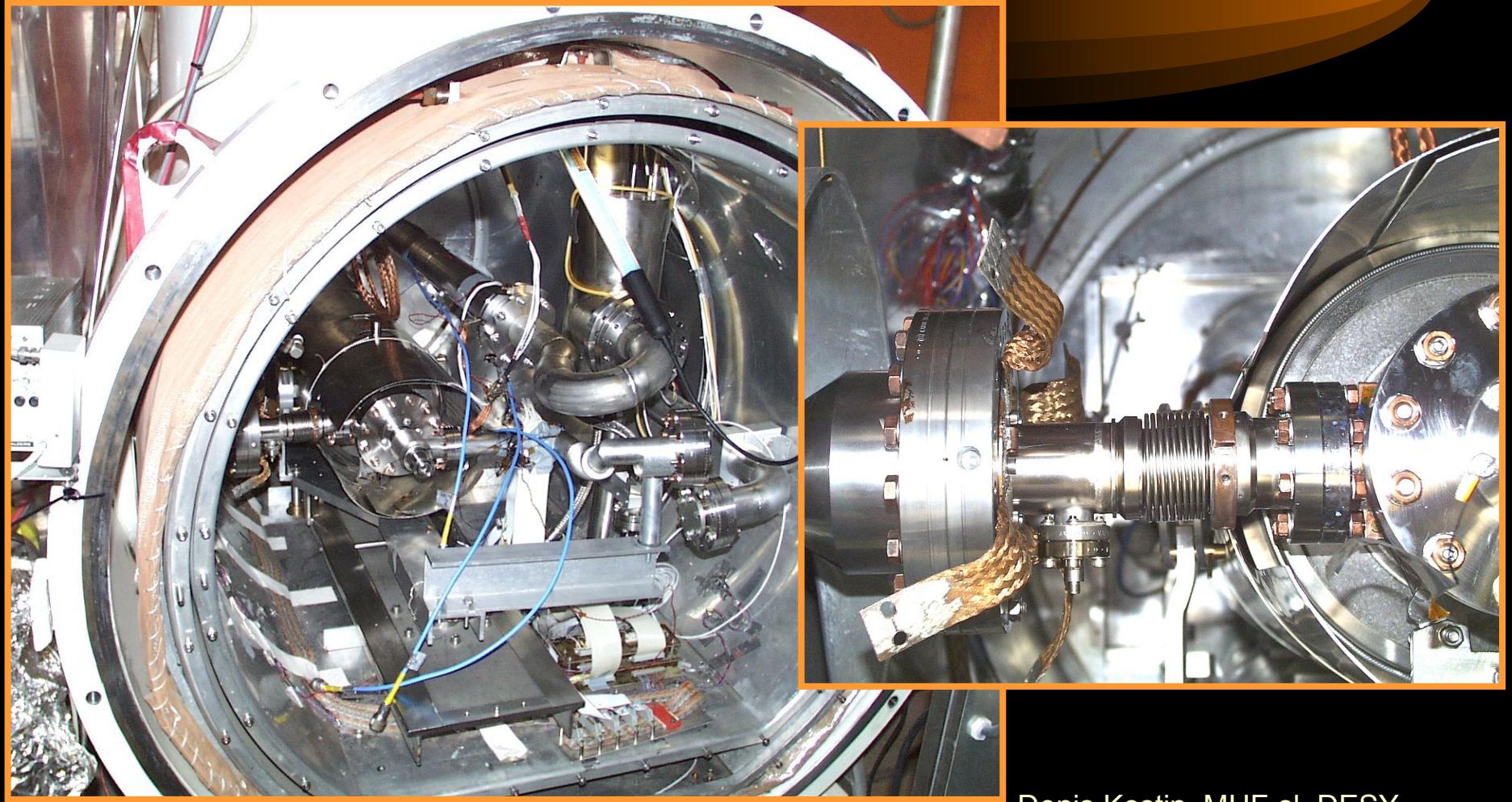
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Cavity with the Cold Part



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Horizontal Cryostat



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Test procedure (1)

1. Coupler processing sequence (standing wave, OFF resonance)

- pulse length 20 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 50 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 100 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 200 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 400 µs, max. power 1.0 MW, power inc. 0.2 dB/min
- pulse length 800 µs, max. power 0.6 MW, power inc. 0.2 dB/min
- pulse length 1300 µs, max. power 0.6 MW, power inc. 0.2 dB/min
- power sweep @ 1.3ms pulse, 50..600 kW of power

2. Coupler processing limits

- e- pick-up IL signal: 5mA (1.2V on the IL card)
- Light (PM) IL signal: 1Lux (10V on the IL card)
- Vacuum pressure: 10^{-6} mbar
- Ceramics temperature: 85°C
- WG sparks: stop if any

Test procedure (2)

Coupler processing sequence (standing wave, ON resonance)

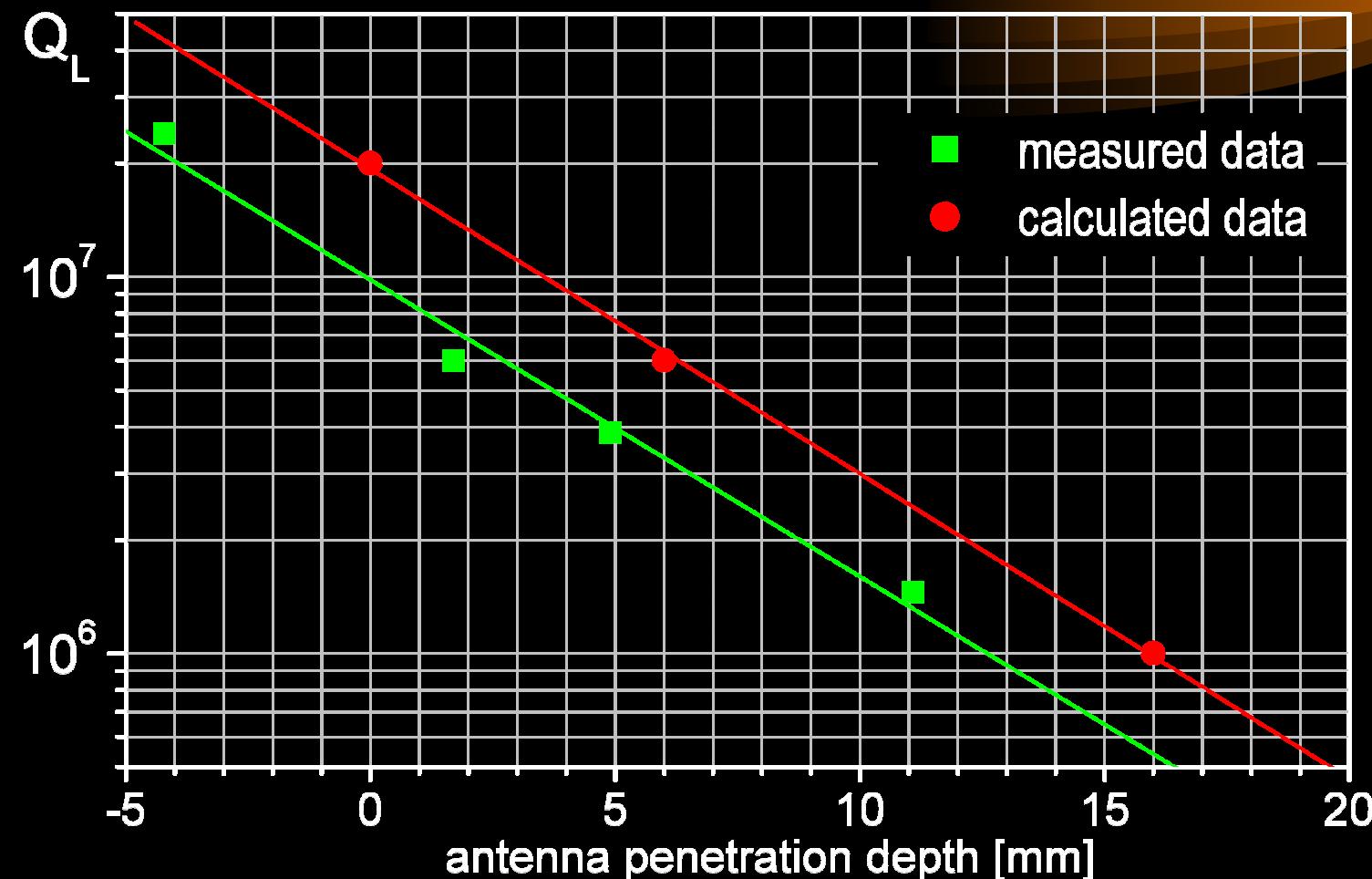
- pulse length 20 µs, max. power 1.0 MW, power inc. 0.2dB/min
- pulse length 50 µs, max. power 1.0 MW, power inc. 0.2dB/min
- pulse length 100 µs, max. power 1.0 MW, power inc. 0.2dB/min
- pulse length 200 µs, max. power 1.0 MW, power inc. 0.2dB/min
- pulse length 400 µs, max. power 330 kW, power inc. 0.2dB/min
- pulse length 500 µs + 100, 200, 400, 800 µs flat top,
max. power 250 kW, power inc. 0.2dB/min
- power sweep @ 1.3 ms = 500 µs + 800 µs flat top pulse,
50..250kW of power, power inc. 0.2 dB/min

rep.rate of 2 Hz

(Processing of the cavity together with the coupler)

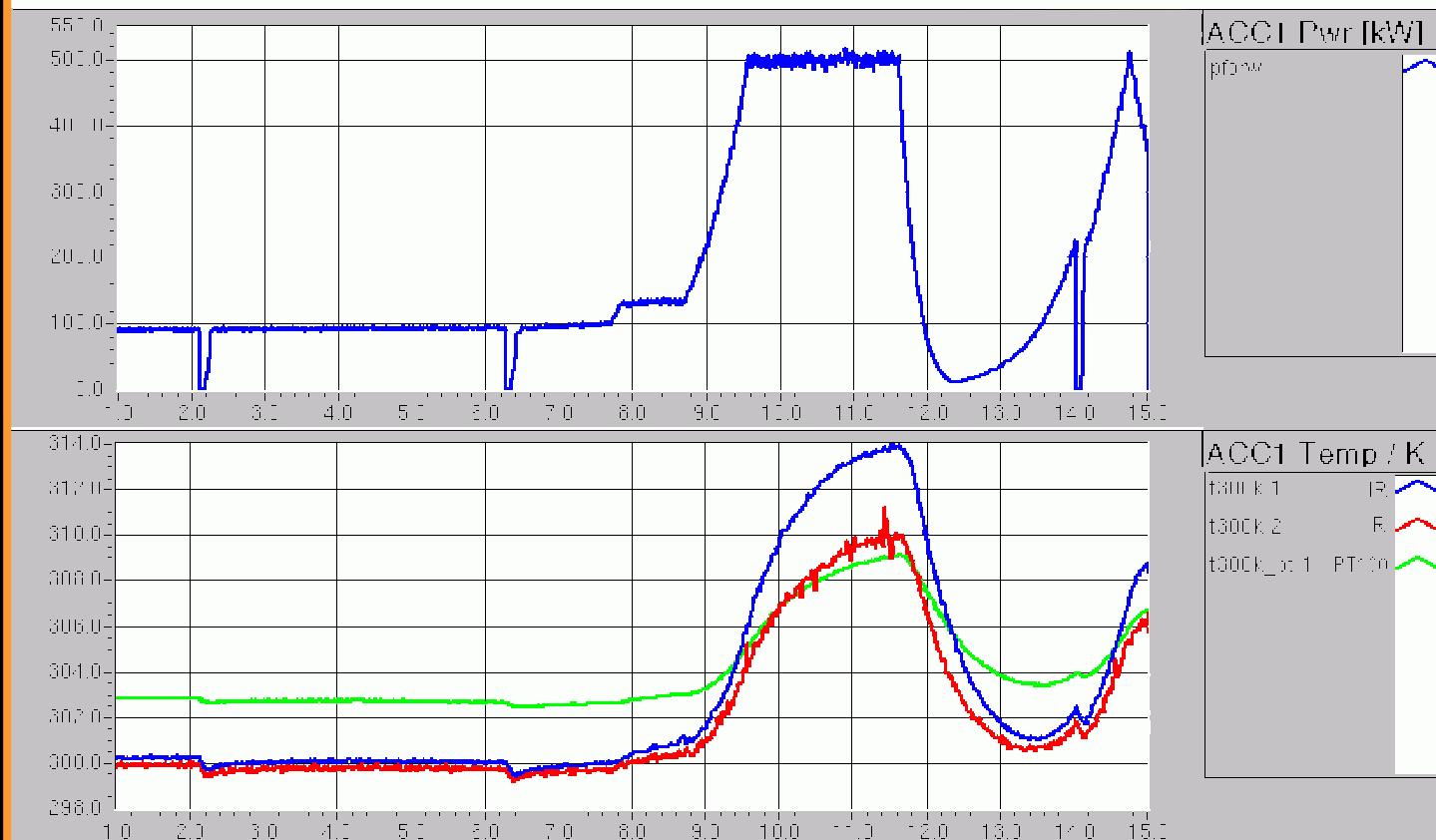
Loaded Q-factor

Cavity: AC60. Coupler: D3C18.

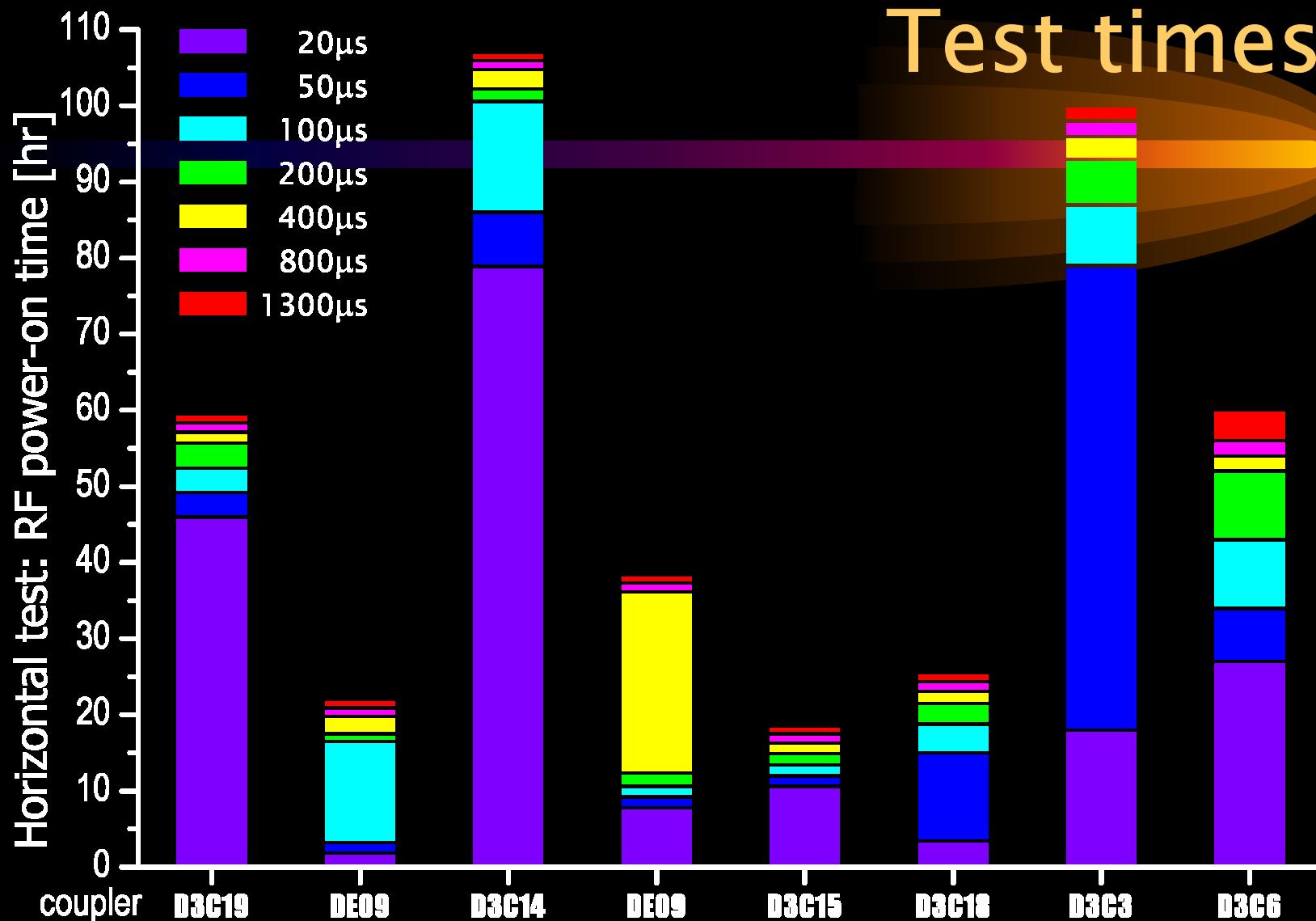


PT100 vs IR temp.sensor

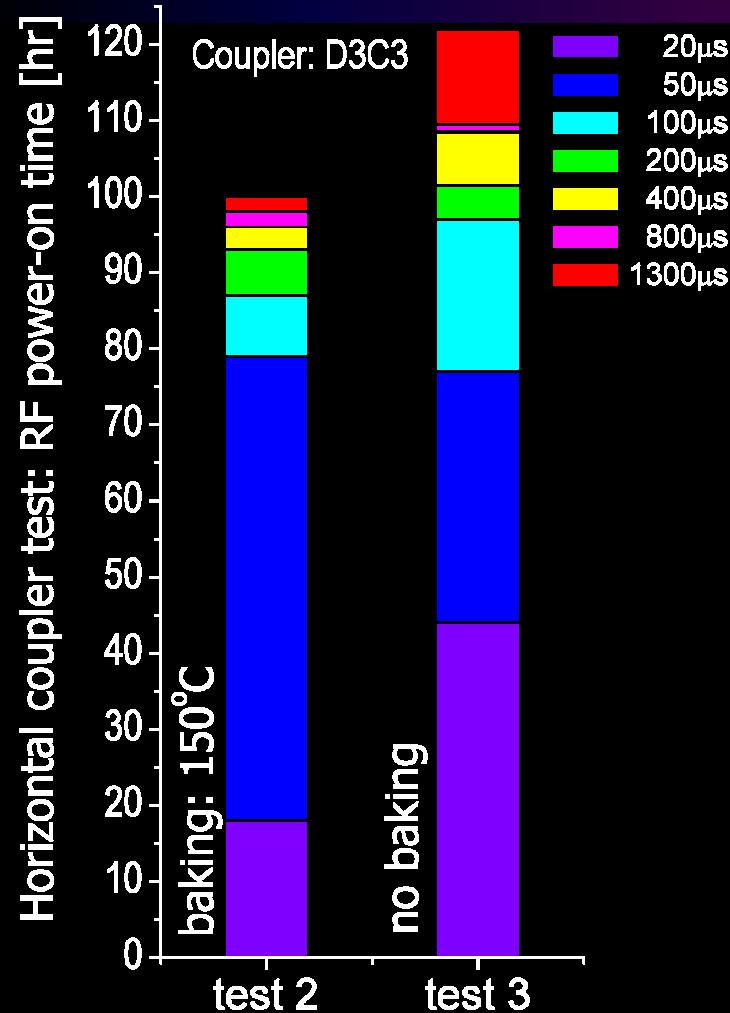
ACCI: warm TTF III coupler ceramics temperature measurement during coupler processing.
IR/PT100 sensors. Pulse length 1.3ms (off resonance).



Test times



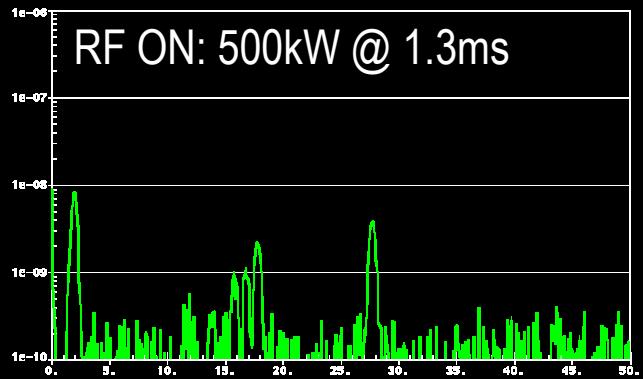
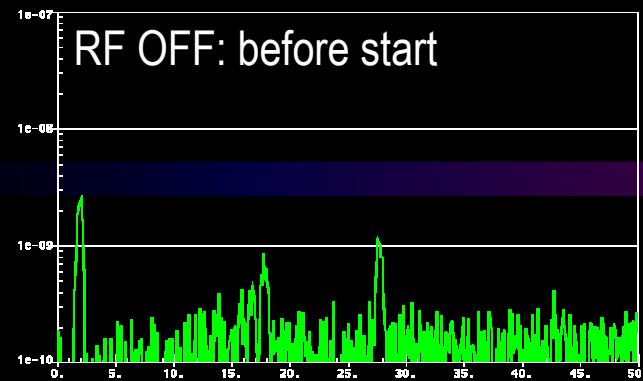
Baking: do we need it ?



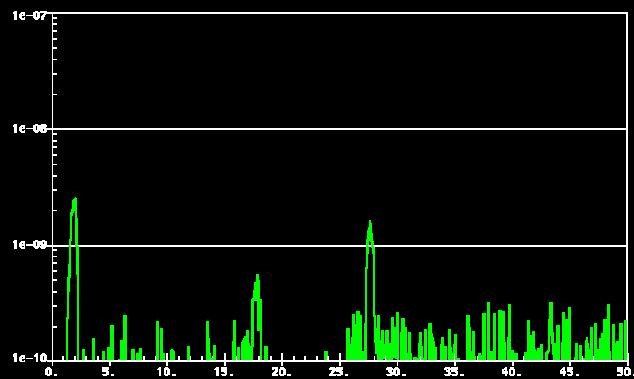
In order to evaluate the importance of the baking of the coupler before the RF test last coupler processing at the horizontal test stand was done without baking @ 150°C. No major difference in processing time observed, still the processing took a little longer. Most of the processing time went to treat the cold part in both cases (because of SW mode). Not baked case shows water rests in the mass spectrum.

Mass Spectrum

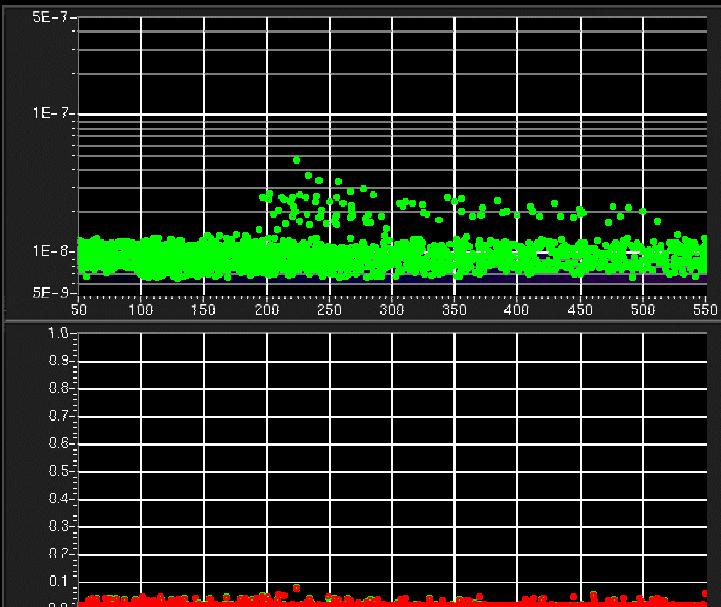
Without baking



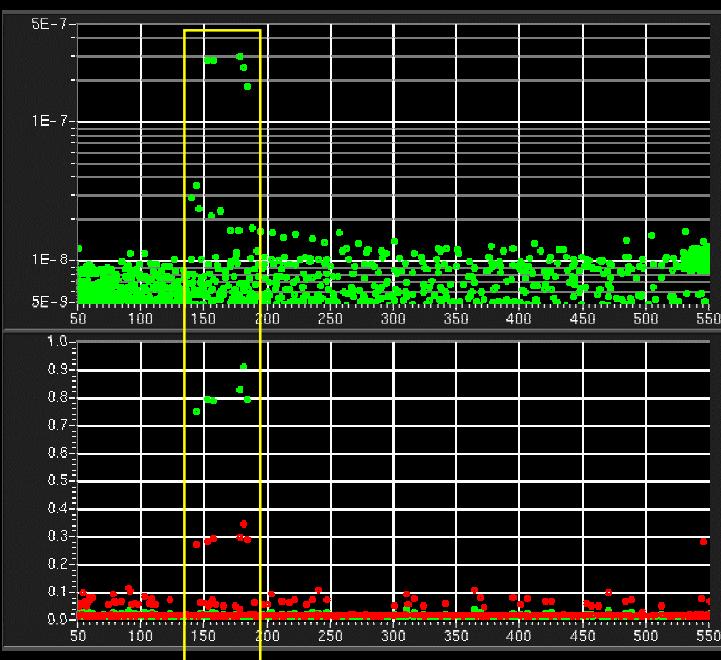
Baked vacuum system



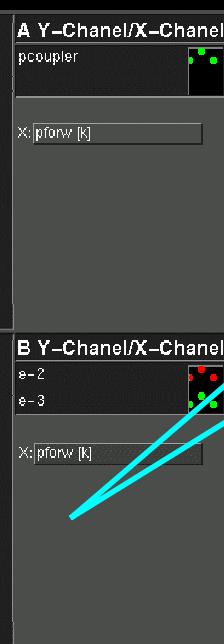
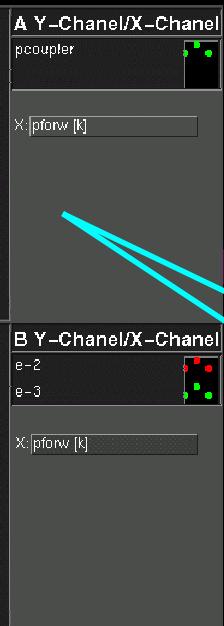
Multipacting



Coupler: D3C3, test: 2
Baked @ 150°C



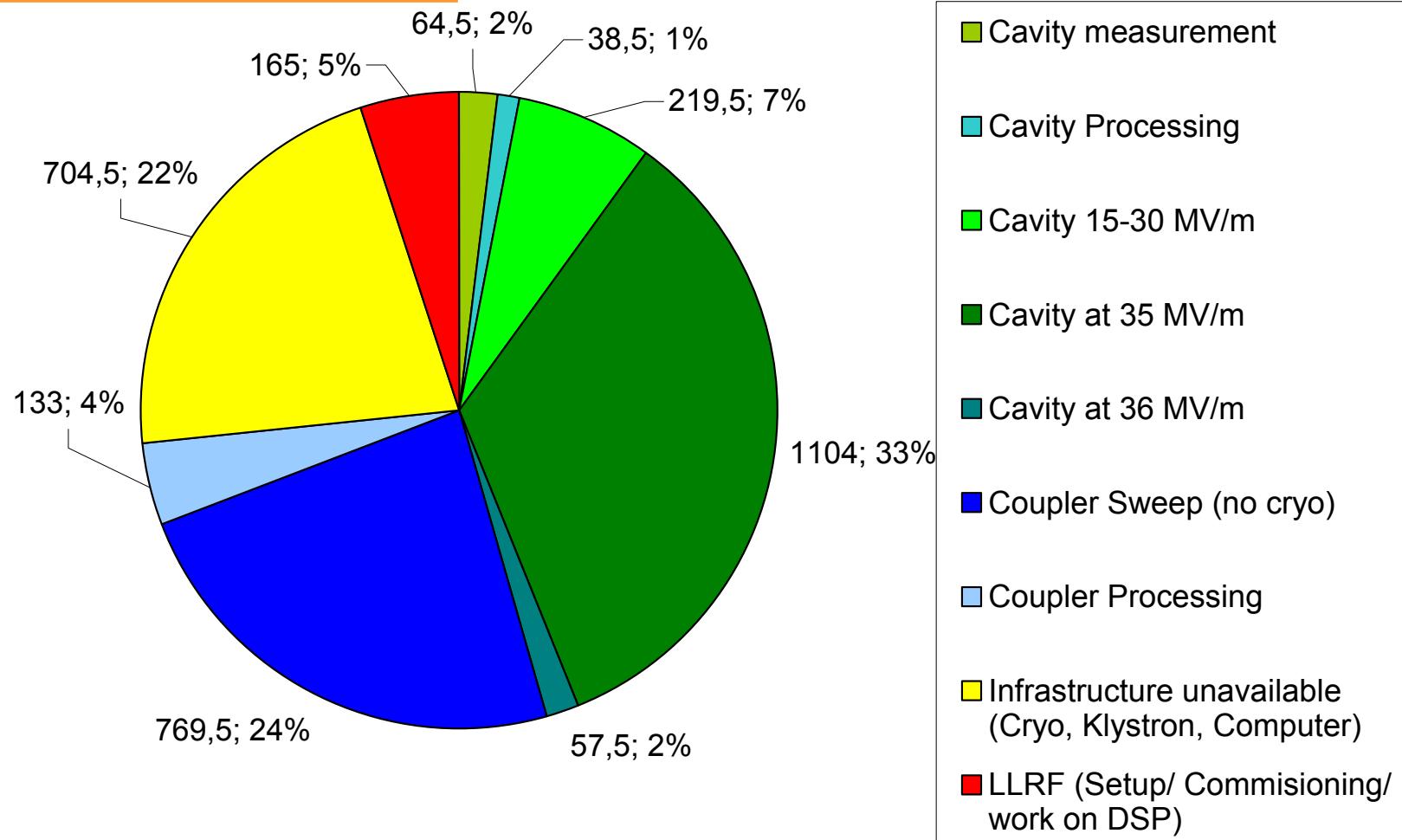
Coupler: D3C3, test: 3
Not Baked



Power sweep @1.3ms 50..550kW

AC73 long run test

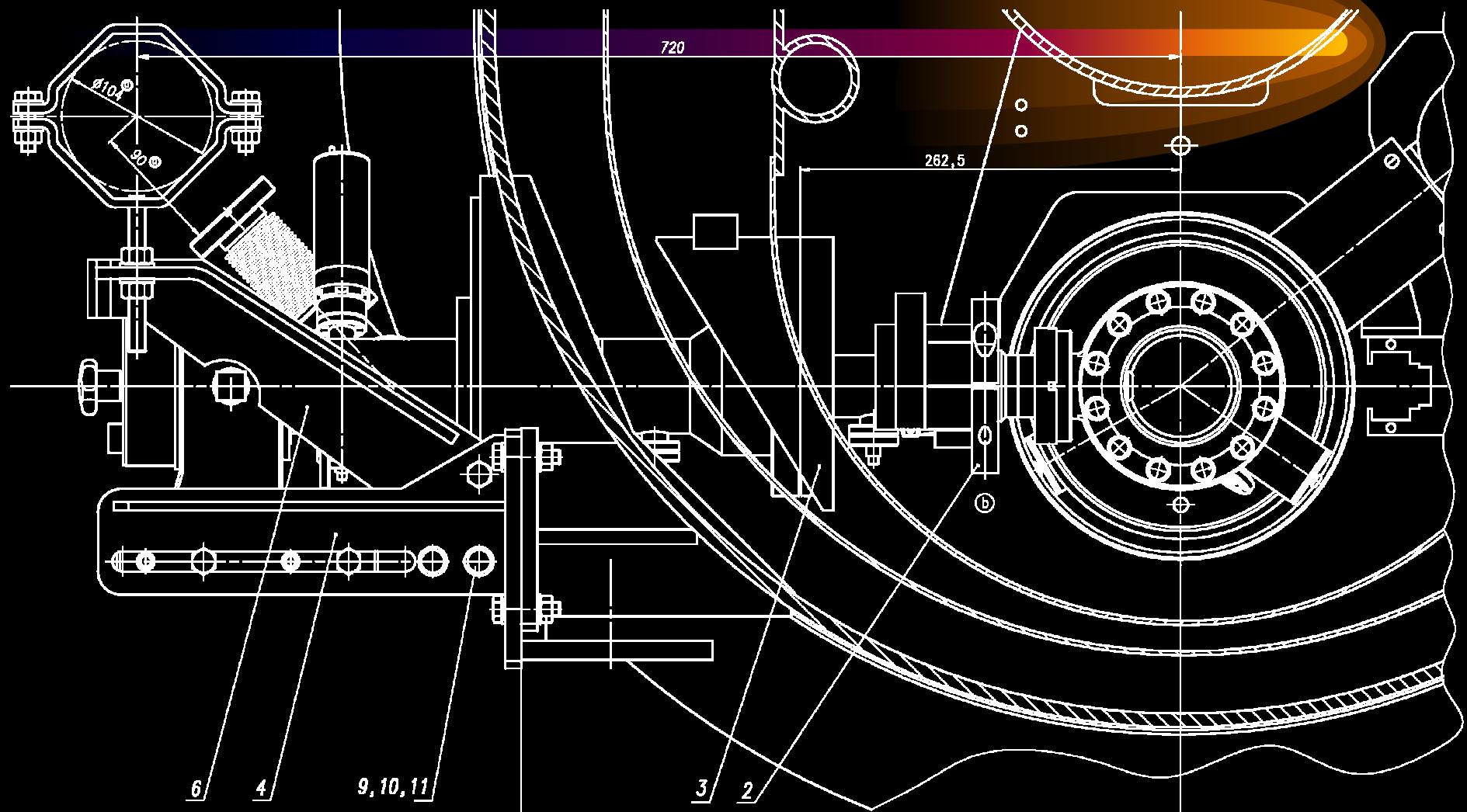
Total time RF on: 2400 hours



Contributed by L.Lilje, DESY

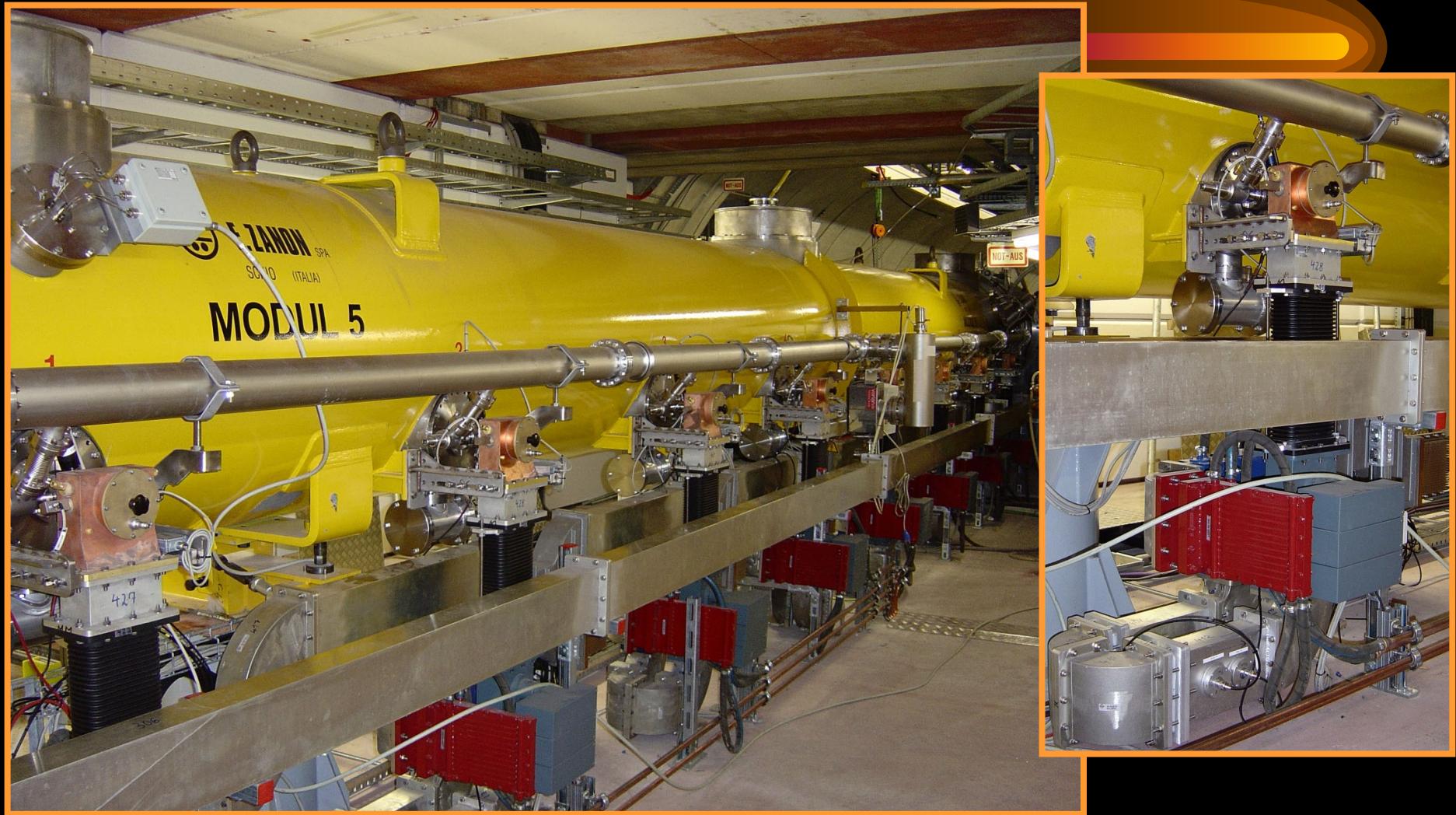
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5. TTF Accelerating Module



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TTF Module 5



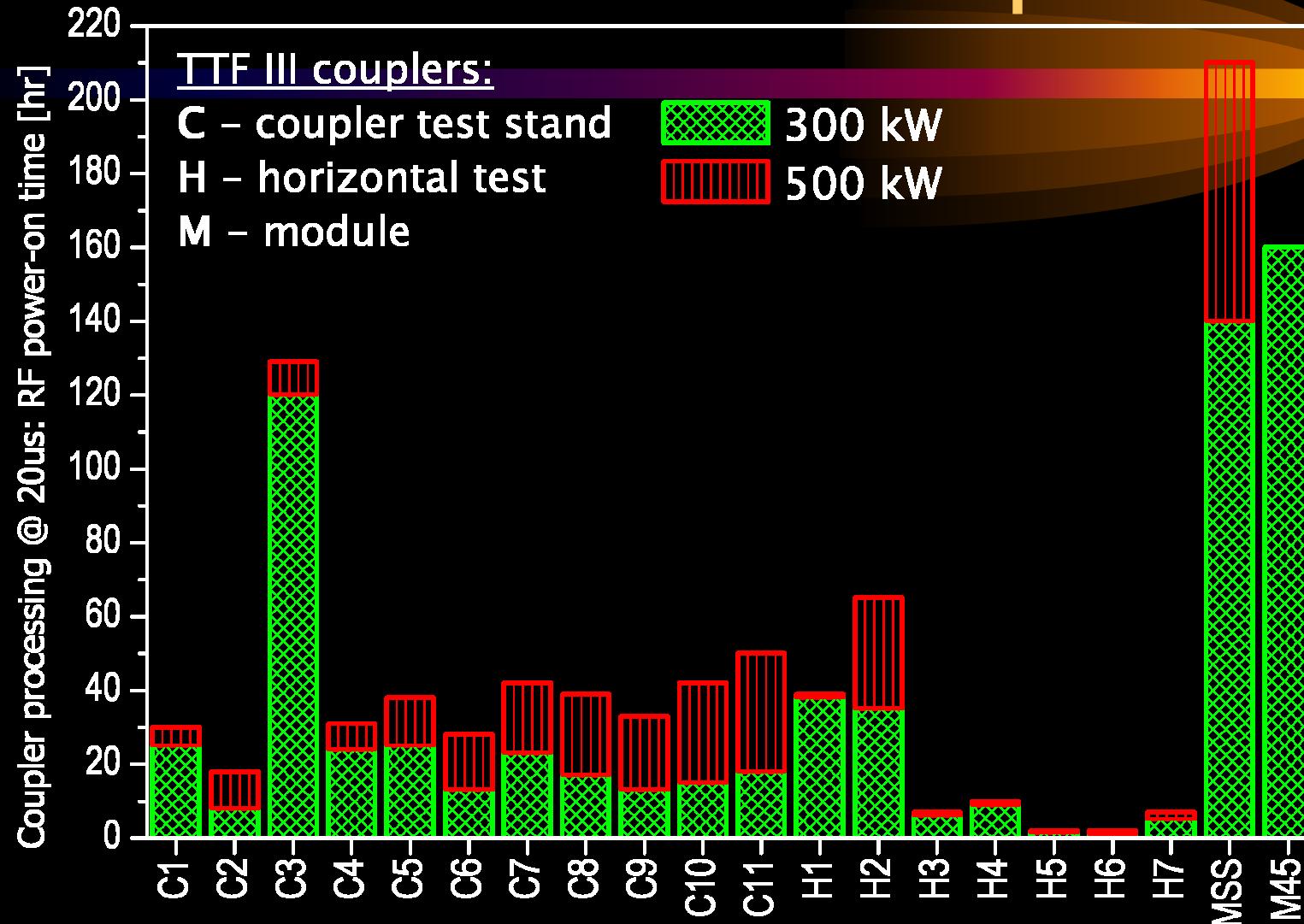
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TTF Module 5 performance



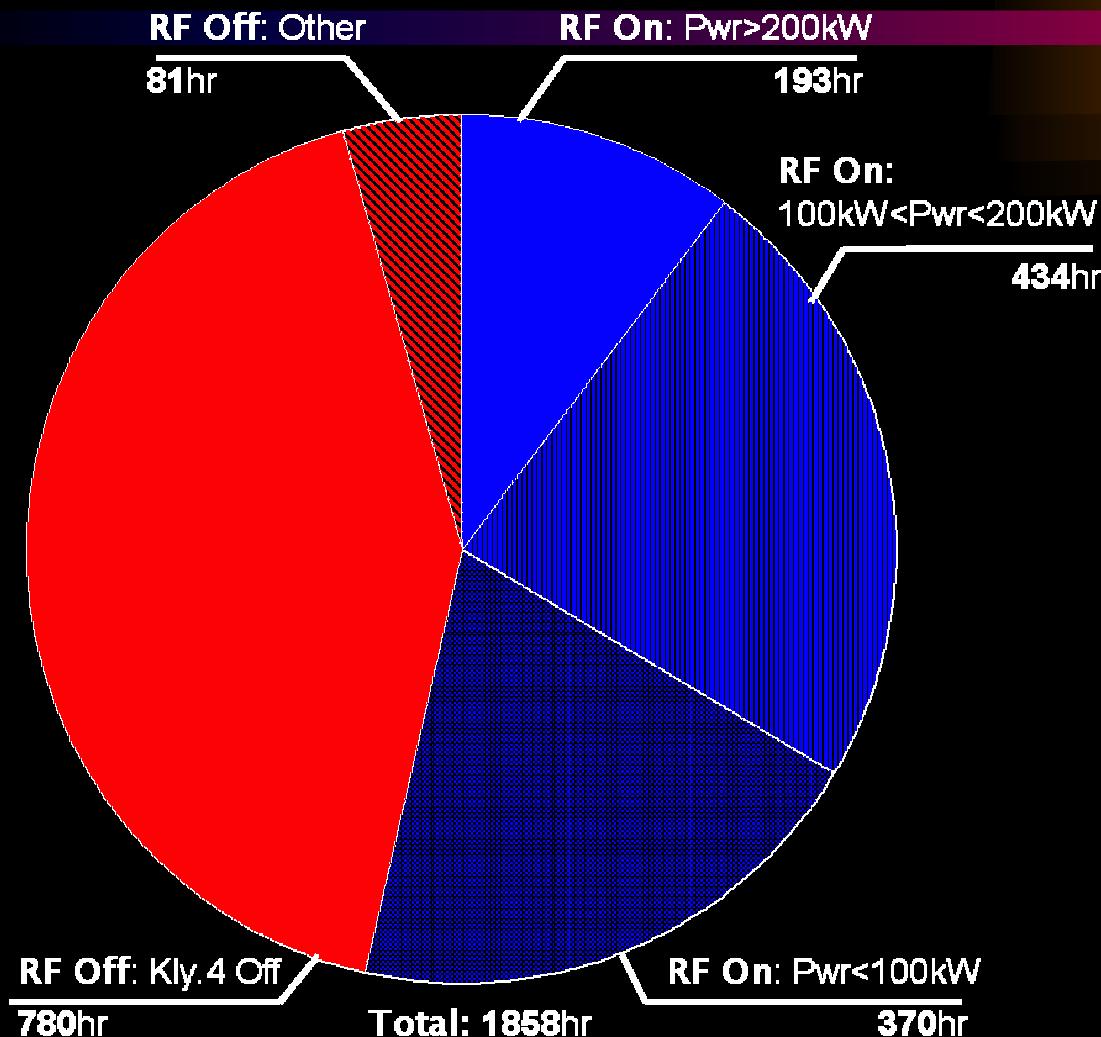
1. ACC5 / Module5, tested at the repetition rate of 5Hz was operating at the accelerating gradient of 25MV/m, 500 + 800 μ s full length flat-top pulse and cavities quality factor of 8×10^9 . Pulsed input power 220 kW.
2. Cavities 1,2,3,4,5,7 @ Module 5 achieved the maximum accelerating gradient of 30 MV/m @ 1 Hz, limited by available power of 330 kW.
3. X-rays screening of the input couplers at ACC5 showed the right coupler antennae alignment.

Test times comparison



Test statistics

Modules 4 and 5 couplers processing time



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Module vs Test Stand

1. No coupler baking *in situ* @ Module.
2. Maximum power of 350 kW @ Module: higher power for short pulses 20..100 μ s not available.
3. 8 or more couplers are processed together @ Module: processing in serial rather than parallel.
4. 8 couplers pumped out together, different effective pumping speeds (15 l/s module, 4 l/s hor.test).
5. Light and Spark detectors affected by radiation.

6. Conclusions



1. TTF III coupler design is well established now and is to be used for new TTF modules, could be used for the X-FEL accelerating modules with some minor improvements.
2. 22 couplers successfully tested at the coupler test stand showed very good performance for maximum pulsed power up to 1 MW and 1.3 ms pulse length.
3. 7 couplers successfully tested at the horizontal cavity test stand with achieved maximum accelerating gradient of 35 MV/m.
4. 10 couplers successfully tested at the Superstructure module (2) and Module 5 (8) in the TTF Linac.
5. Longer processing times for the modules must be investigated more carefully taking into account the new data.